UDC 621.396.62-182.3
621.317.32
621.3.029.53

1969
THE QUEEN'S AWARD TO INDUSTRY

BBC

RESEARCH DEPARTMENT

REPORT

A medium-wave field-strength measuring receiver

No. 1972/1

Research Department, Engineering Division
THE BRITISH BROADCASTING CORPORATION

RESEARCH DEPARTMENT

A MEDIUM-WAVE FIELD-STRENGTH MEASURING RECEIVER

Research Department Report No. **1972/1**
UDC 621.396.62–182.3
621.317.32
621.3.029.53

This Report may not be reproduced in any form without the written permission of the British Broadcasting Corporation.

It uses SI units in accordance with B.S. document PD 5686.

D.E. Susans, M.I.E.E., M.I.E.R.E.
R.D.C. Thoday, M.I.E.R.E.
M.J. Buckley

Head of Research Department

RA-93

Research Department Report No. **1972/1**

A MEDIUM-WAVE FIELD-STRENGTH MEASURING RECEIVER

Section Title Page

Summary 1

1. Introduction 1

2. Description 1

2.1. The loop aerial 1
2.2. The calibration oscillator and tuning unit 2
2.3. The receiver 4

3. Operation of the system 4

4. Initial calibration 4

5. Performance 4

(RA-93)

February 1972

Research Department Report No. 1972/1
UDC 621.396.62–182.3
621.317.32
621.3.029.53

A MEDIUM-WAVE FIELD-STRENGTH MEASURING RECEIVER

Summary

This report describes a field-strength measuring system for the frequency range 510 – 1610 kHz. It incorporates a commercially available receiver, with some modifications. The loop aerial used with this receiver is mounted on the roof of a Commer 2000 metal-bodied vehicle. The calibration arrangement, using a specially constructed unit with an oscillator, permits the receiver to give direct readings of the field strength over the range 30 μV/m to 10 V/m. The overall error, including that due to arbitrary orientation of the vehicle, is less than ±10%.

1. Introduction

Mobile medium-wave field-strength measuring receivers use a loop aerial to sample the r.f. field being measured. If the sample is to give a true representation of the field then the loop must be clear of any adjacent conductors which distort this field. In the past this has been achieved either by using portable receivers and carrying them clear of any conducting objects or by using a measuring set in a non-metallic bodied vehicle.

With a vehicle of this type great care must be taken to avoid any wiring for lighting etc. which would couple to the loop. Structural metal components above the floor must be avoided as must metal surrounds to windscreens. These requirements are not met by any available commercial vehicle and are, in any case, not compatible with those for field strength measurements in other bands.

To avoid these problems it was decided to attempt to mount a suitable loop aerial above the centre of the roof of a Commer 2000 vehicle normally used for u.h.f. measurements. To permit the loop to be turned during the measurements it is mounted on a short, rotating stub mast. Since the vehicle distorts the field to be measured, a correction factor for the mean change of field is built into the equipment.

The overall measurement range of the system, 30 μV/m to 10 V/m, is sufficient to deal with both low fields and polar diagram measurements close to high power transmitters.

2. Description

The equipment comprises three units: (i) a loop aerial assembly, (ii) a calibration oscillator and loop tuning unit and (iii) a medium-wave receiver. These units are designed to obtain their power from the vehicle battery. The complete assembly in the vehicle is shown in Figure 1.

2.1. The loop aerial

The loop aerial consists of a five turn screened loop of 593 mm diameter mounted with its centre 600 mm above the roof of the vehicle. To minimise impairment of loop performance by voltages produced by unbalanced capacitance to ground, the screening conductor is split at the top of the loop to provide geometrical symmetry about the supporting mast. A polythene insulator is used to maintain the gap width between the screen conductors and to provide the necessary weather proofing.

For ease of construction the winding consists of five turns of semi-air-spaced coaxial cable inner conductor and polythene insulation (the outer braiding having been removed) which occpuies most of the internal volume of the screening conductor. The arrangement leaves little space for movement of the winding following mechanical shock and provides a reasonably low self capacitance. The measured inductance is 38 μH, and the self capacitance with one winding terminal grounded is 110 pF.

One end of the loop is taken to the tuning unit while the other is taken to earth (at r.f.) via a small inductor which is used as a low impedance into which a current can be injected for calibration. By this means a known voltage is developed across the inductor which, for a given current, increases with frequency, thus giving first-order compensation for the frequency variation of the e.m.f. induced in the loop by an external signal. To keep the calibration current at a convenient level the injection inductor forms part of an auto-transformer as shown in

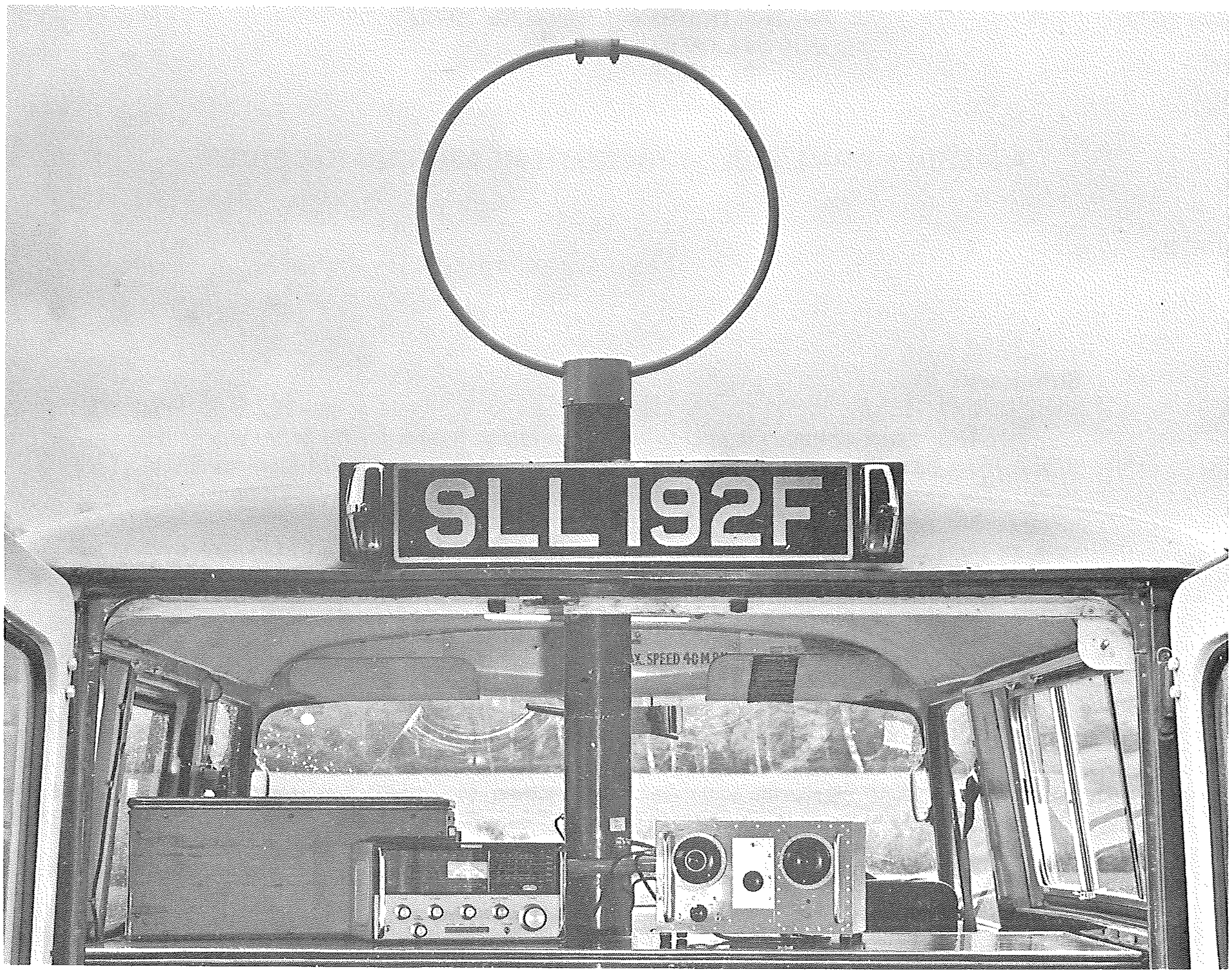

Fig. 1 - The assembled system

Figure 2. The transistor driving this auto-transformer employs emitter current feed-back and is fed from the calibration oscillator attenuator. Its output impedance is very high in comparison with that of the inductor, so that controlled currents can be injected into the transformer for calibration. L2, which has a reactance small compared to R1, is inserted to compensate for a second-order frequency-dependent calibration error caused by a number of instrumental effects arising in the calibration oscillator and loop. The loop is tuned to obtain adequate sensitivity, and to maintain reasonable values of the tuning capacitance it is necessary to keep stray capacitances across the loop to a minimum. To help achieve this aim the support mast is used as the outer conductor of a coaxial lead into the vehicle. The output from the mast is then connected to the tuning unit by a 1·05 m length of low-capacitance cable. The power supply for the injection transistor is obtained via the loop from the loop tuning unit.

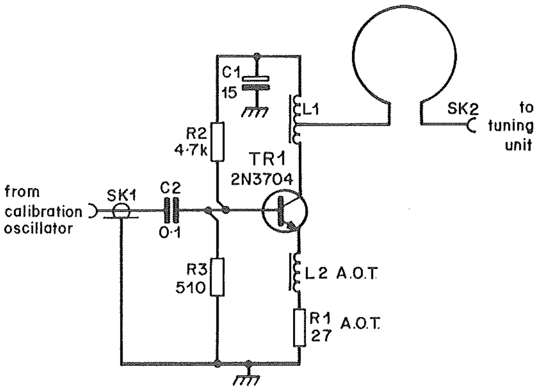

Fig. 2 - Loop aerial unit

2.2. The calibration oscillator and tuning unit

The three main requirements of the calibration oscillator are (a) it should have a constant output level, (b) it should have a very low stray field and (c) it should have a low harmonic content. It is also helpful to have some indication that the output is at the correct level in order to avoid errors resulting from slowly failing batteries.

The stray fields are kept low by using an oscillator without coils and by using a well screened box with the power supply leads adequately decoupled and an insulating control shaft to the tuning capacitor enclosed in a long,

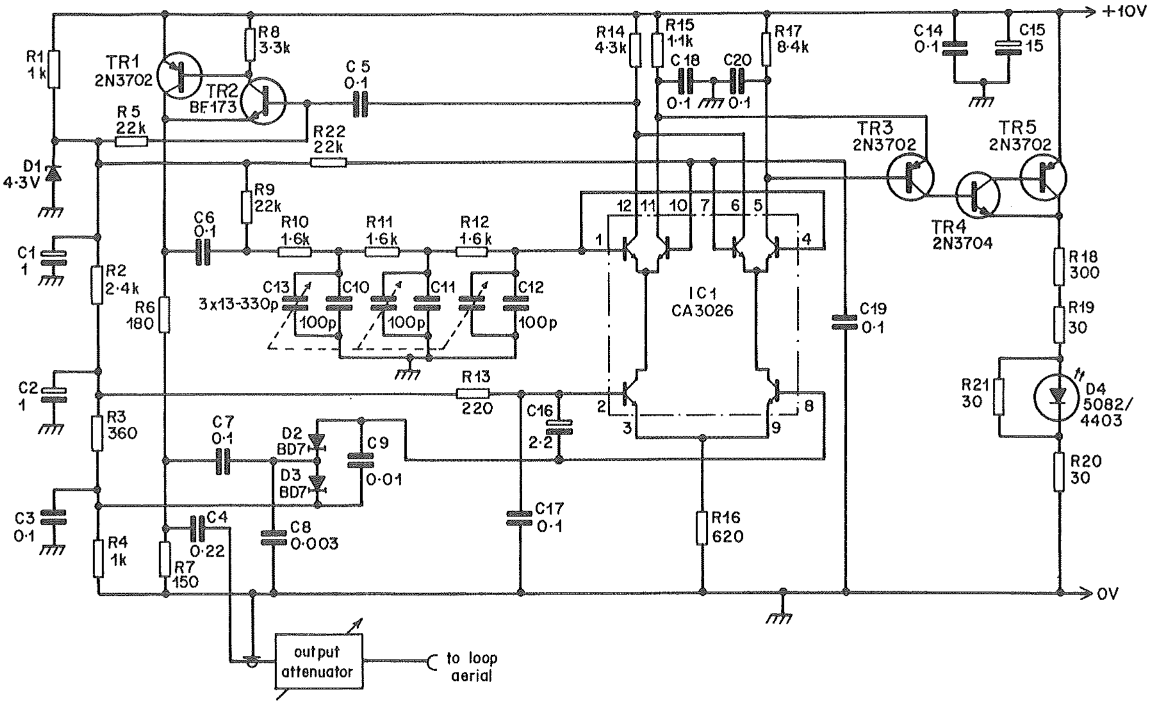

Fig. 3 - Calibration oscillator

small-bore tube. The circuit used (Figure 3) is a three-section resistance-capacitance phase-shift oscillator. The maintaining amplifier consists of a double balanced amplifier integrated circuit IC1.

The gain of the maintaining amplifier is controlled by varying the direct voltage applied to the base of the lower right-hand transistor (pin 8). If there were no r.f. output this potential would raise the gain to its maximum. As the r.f. output increases the d.c. produced by the voltage-doubling detector D2, D3 increases and, when the output is sufficient, the gain is rapidly reduced; the output is thus stabilised at a known value. Backward diodes are used in this detector as these give efficient detection at the levels involved (400 mV p-p) and have very low temperature coefficients. A compound emitter follower TR1, 2 at the amplifier output feeds the detector and the feedback network. The output attenuator is a commercial item slightly modified to permit it to be fed from a very low impedance source with a minimum of loss. It has eleven steps of 10 dB corresponding to the full scale ranges of the instrument from 100 µV/m to 10 V/m.

One of the amplifier collectors (5) which is not in the feedback chain is used as a d.c. drive to transistors TR3, 4 and 5. When the amplifier is driven by the detector so as to reduce its gain, the d.c. conditions are such that the gallium-arsenide light-emitting diode D4 lights, indicating that the oscillator is giving its standard output. A perspex light pipe is used to convey this light to the outside of the box through a long metal tube so as to avoid r.f. leakage.

The tuning unit (Figure 4) provides means of tuning the loop by either one or four sections of a variable capacitor dependent on the frequency. The resonant circuit so formed is damped by a fixed resistor chain. Taps on this chain supply a wide-band amplifier IC1, which has a high input impedance and a 75-ohm output to feed the receiver. In the interests of a good signal-to-noise ratio the full resonant voltage is applied to the amplifier at low signal levels. At higher signal levels the input to the amplifier is progressively attenuated in six 10 dB steps by an attenuator ganged with that of the calibration oscillator. At these levels only small adjustments to the receiver gain are required.

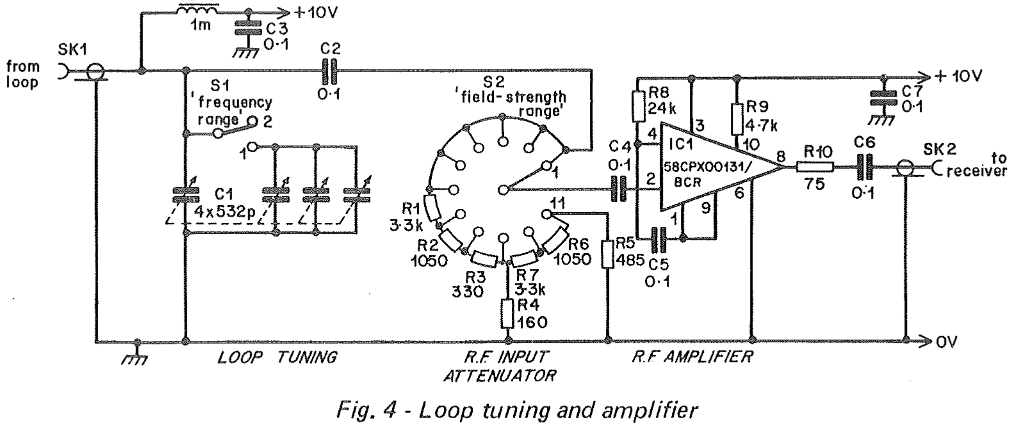

Fig. 4 - Loop tuning and amplifier

The power supplies for the calibration oscillator and r.f. amplifier are derived from a pair of 'DEAC' 6·5V nickel-cadmium accumulators mounted within the unit, providing a 13V output which is stabilised to +10V. Two pairs of accumulators are provided, one pair being recharged from the vehicle battery while the other is in use. Each pair of batteries is provided with a pair of chargers. This system of charging avoids any connections between the vehicle battery and the calibration oscillator.

2.3. The receiver

The receiver is an Eddystone EC-10 (Mark II) receiver modified for this application. All d.c. earths between the receiver and its case have been removed, so as to permit connection to vehicle batteries with either pole earthed, the connections between the printed cards and earth being replaced by 0·1 μF by-pass capacitors. A meter responding to the current in the detector has been fitted to indicate the field strength. The meter zero has been suppressed so as to give a more linear output indication and the original i.f. gain control replaced by a multi-turn potentiometer in order to permit finer adjustment of the i.f. gain.

A 9V stabilised power supply run from the vehicle battery has been fitted in the battery compartment of the receiver.

3. Operation of the system

The method of operation is as follows:

1. Switch on the receiver and loop amplifier.
2. Tune the receiver to the wanted station (A.G.C. off) adjusting the receiver gain and loop attenuator as necessary.
3. Adjust the loop tuning and orientation for a maximum on the meter, re-adjusting gains as necessary.
4. Switch on the calibration oscillator and tune for zero beat with the wanted signal. Switch off the calibration oscillator.
5. Rotate the loop to give a minimum on the meter.
6. Switch on the calibration oscillator and adjust the i.f. gain control for full scale deflection on the meter. Switch off the calibration oscillator.
7. Rotate the loop for a maximum on the meter. If this is not on the calibrated part of the scale it will be necessary to repeat 5–7 with the loop attenuator on an adjacent position.
8. The loop attenuator setting now gives the full-scale reading of the meter and the field strength can be read off the meter directly from the appropriate scale.
9. Whenever the attenuator range is changed it is essential to recalibrate the meter.

4. Initial calibration

When performing the initial calibration of a new equipment, four types of checks must be made. The first of these is to check the calibration oscillator output attenuator. This may be checked against a standard attenuator by standard techniques. The second check is to verify that the calibration is independent of frequency. For the third check, the absolute field-strength calibration at one frequency must be determined. Finally, an estimate of the azimuthal errors should be made. The usual method of checking the frequency law is to place the receiver very close to a loop aerial passing a constant r.f. current at various frequencies, the receiver then indicating a constant field. This is not possible with this system since the vehicle distorts the field in an unpredictable manner. To overcome this problem a small portable measuring receiver was checked in this manner and used to measure the r.f. fields of both broadcast transmissions and locally generated fields radiated by vertical wires at a distance of several hundred meters. The portable receiver was then replaced by the vehicle system which could now be calibrated by reference to these measured fields.

The absolute field strength calibration was carried out by comparison with a calibrated portable field-strength meter. The final calibration was checked by an independent calculation from the loop and injection coil constants together with the known value of the injected current. When an allowance was made for the apparent increase in field due to the presence of the vehicle and its directional properties (see below) there was a close agreement between the two methods of calibration.

The two effects of the vehicle are (a) to raise the apparent field-strength and (b) to give an indication varying with the direction of arrival of the signal. If the loop is replaced by the portable instrument, then removing the van from under the measuring set gives a drop in the measured field strength of about 15%. A correction for the mean value of this error has been made by means of an adjustment of the calibration current injection circuit.

Measurements made whilst rotating the van about a vertical axis enable a plot (Figure 5) to be made of the sensitivity as a function of the direction of arrival of the signal. This was found to be virtually independent of frequency and did not exceed ±5%. A correction for this azimuth error can be made by reference to Figure 5.

If a different type of vehicle were used the calibration injection circuit would require re-adjustment.

5. Performance

Tests on this equipment show that over a frequency range of 510–1610 kHz and a field-strength range of 30 μV/m – 10 V/m an accuracy of better than ±10% has been achieved. About half of this error could be compensated for by a correction for the orientation of the vehicle.

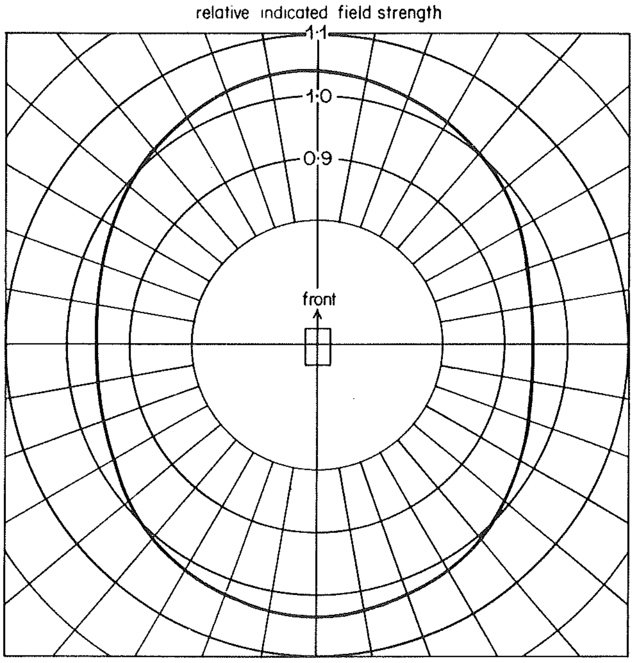

Fig. 5 - Effect of vehicle on system sensitivity